Accurately Reproducing Pantone Colors on Digital Presses

By Anne Howard

Graphic Communication Department
College of Liberal Arts
California Polytechnic State University
June 2012

Abstract

Anne Howard
Graphic Communication Department, June 2012
Advisor: Dr. Xiaoying Rong

The purpose of this study was to find out how accurately digital presses reproduce Pantone spot colors. The Pantone Matching System is a printing industry standard for spot colors. Because digital printing is becoming more popular, this study was intended to help designers decide on whether they should print Pantone colors on digital presses and expect to see similar colors on paper as they do on a computer monitor.

This study investigated how a Xerox DocuColor 2060, Ricoh Pro C900s, and a Konica Minolta bizhub Press C8000 with default settings could print 45 Pantone colors from the Uncoated Solid color book with only the use of cyan, magenta, yellow and black toner. After creating a profile with a GRACoL target sheet, the 45 colors were printed again, measured and compared to the original Pantone Swatch book.

Results from this study showed that the profile helped correct the DocuColor color output, however, the Konica Minolta and Ricoh color outputs generally produced the same as they did without the profile. The Konica Minolta and Ricoh have much newer versions of the EFI Fiery RIPs than the DocuColor so they are more likely to interpret Pantone colors the same way as when a profile is used. If printers are using newer presses, they should expect to see consistent color output of Pantone colors with or without profiles when using default settings.

Table of Contents

List of Tables

List of Figures

Chapter 1: Introduction

Statement of the Problem

Digital printing is becoming increasingly popular in the printing industry because of its ability to produce short-run jobs, ease of use, and low cost of production. However, some attention should be paid to the process in which raster image processors, or RIPs, for digital presses convert colors within print files, particularly Pantone colors, and how well the default, or factory settings, of digital presses reproduce those colors. Pantone colors, or spot colors, are made up of unique pigments, not cyan, magenta, yellow and black, the four process colors of print. To accurately reproduce a color with toner on a digital press, or any type of press, with the use of solely the four process colors is a difficult task. When a designer has a file they need to have reprinted multiples times, they may bring it to different digital printers with different RIPs. They would expect the colors to look similar, but that does not happen all of the time. This project seeks to examine how accurately three different brands of digital presses with similar versions of raster image processors reproduce a Pantone target test sheet compared to a true Pantone swatch book when their settings are set to default.

Raster image processors are what convert files to a language that a digital press will understand in order to print it. When the file has color, the RIP converts that color using its own version of a color lookup table. The problem occurs when RIPs have different versions of the same color and they are converted differently, which results in a variation of the original color in the final product. Testing the same target sheet on three calibrated printers with similar RIPs will compare how similar or different the Pantone colors are reproduced by the presses. Also, making sure there are no customized settings within the printer and turning them all to defaults will help determine how the whole printer's system for each press produces color. Measurements with a spectrophotometer will be taken to verify the color differences on identical paper so an accurate comparison can be made as to which printer and RIP produced the closest version of Pantone colors.

Significance of the Problem

The conversion of color by the RIP determines how the color will be printed, along with the internal settings within a printer. The default color settings for RIPs and calibrated presses are set by the manufactures and they determined that with those settings, the machinery is able to produce color accurately with no adjustments. If a digital printer cannot closely reproduce a Pantone color on a digital press, designers may second-guess their use of the Pantone Matching System, or possibly avoid using digital printing altogether. If this project can determine the similarities of CMYK and Pantone colors and how close CMYK can create Pantone when they are printed on the same substrate and run through similar RIPs with default settings, graphic designers may be more willing to use the Pantone Matching System than before.

Interest in the Problem

The Pantone Matching System provides standardization for spot color reproduction for print and when a graphic designer has their work digitally printed for their customers, they should expect accurate colors. The combination of the growing status and capabilities of digital printing and the use of spot colors have sparked interest in the relationship between the two. Designers use spot colors when CMYK mixtures do not do the job and they expect the color on their computer screen to look the same as the color on a piece of paper. Pantone colors expand the limits of the printing color gamut and therefore expand printing and designing possibilities. Matching spot colors is an issue in the industry today and this project further explore the limits of how process colors recreate Pantone colors.

Chapter Two: Literature Review

The Pantone Matching System (PMS) has become the leading color reference system for "selecting, specifying, matching and controlling ink color" in the graphic arts and printing industries ("Pantone: what we do"). With their forever-expanding variety of specialized colors, Pantone has created multiple color systems and guides that all types of designers look to when wanting to create a uniquely colored piece. When much time and effort is put into designing something that includes specific Pantone colors, designers would expect the final printed product to be accurately reproduced. When digitally printed, the file that includes the Pantone colors must go through a raster image processor (RIP) that interprets the colors and is then printed with the use of cyan, magenta, yellow and black toner. Pantone offers a variety of color libraries for designers, however, they may appear differently depending on how the colors are digitally printed and reproduced, so one can measure the color accuracy to compare back to an original swatch using a spectrophotometer.

Pantone Systems & Guides

The PMS consists of thousands of unique color mixtures and is separated into different types of categories for specific purposes and usages. There are systems dedicated strictly for the graphic arts, including printing and publishing, clothing, home furnishing and interior decorating, paints and plastics ("Pantone: what we do"). Because this project aims to compare the accuracy of printed Pantone colors from digital printers, this paper will only focus on the systems created for the graphic arts.

All of the colors within the Pantone Matching System are created by mixing Pantone's fifteen basic colors made from specialized pigments in different amounts ("Solid Color Information"). Those colors include (Table 1):

PANTONE Yellow	PANTONE Red 032
PANTONE Purple	PANTONE Process Blue
PANTONE Yellow 012	PANTONE Rubine Red
PANTONE Violet	PANTONE Green
PANTONE Orange 021	PANTONE Rhodamine Red
PANTONE Blue 072	PANTONE Black
PANTONE Warm Red	PANTONE Transparent White
PANTONE Reflex Blue	

Table 1: The fifteen basic Pantone color pigments that are combined in various amounts to make up the PMS.

The most general guide Pantone distributes is the Pantone Formula Guide. It includes a set of three guides "consisting of 1,114 solid Pantone Colors on coated, uncoated and matte stock [showing] corresponding printing ink formulas for each color, and [a] three-book set of solid chips [that] provides coated, uncoated and matte perforated tear-out chips that can be used for quality control" ("Pantone: what we do"). This particular guide-set would be used for a designer who wanted to use one of the 1,114 colors created using the 15 basic base colors and needed the formula to mix two or more of these colors or to recreate a color and then compare the color quality to the original.

Because Pantone colors are used for print material, as well digital material, there is some difficulty making the two versions look alike. To avoid conversion trouble, Pantone has two types of guides with colors that are achievable using the printing process primary colors of cyan, magenta, yellow and black, or CMYK. They are called the Pantone 4-Color Process Guides, a digital guide that includes over 3,000 colors capable of being accurately reproduced when printed with the four process colors ("Pantone: what we do"). The other guide called the Pantone Color Bridge Guide is a coated and uncoated book-set that aims to "compare solid Pantone colors to their closest possible match in CMYK four-color process that can be achieved on a computer monitor, output device or printing press" ("Pantone: what we do").

The most recent color guide that Pantone announced in 2007 is called the Pantone Goe System. It "was the first completely new color inspiration and specification system for the graphic arts industry since the introduction of the Pantone Matching System in 1962. The System, bringing 2,058 new Pantone Colors to market, is comprised of the Pantone GoeGuide, Pantone GoeSticks and myPantone palettes" ("Pantone Announces," 2008). The GoeSticks consists of a two-volume set of color chip stickers that allow designers to put them on their work to view how the color will appear without having to use damaging attachment methods, like glue or staples ("Pantone Announces," 2008).

Pantone versus CMYK

Cyan, magenta, yellow and black, the four process colors of print, are only able to reproduce a limited amount of the visual color gamut (Sharma, 2008). With the use of Pantone inks, the print color gamut is enhanced, represented by the black dots expanding passed the pink CMYK limits in Figure 1. The challenge comes when a spot color that appears on screen is out of the limits of the CMYK color gamut, needs to be reproduced for print material using only the four process colors, and the color does not come from the Pantone 4-Color Process Guides. Pantone colors look differently on a monitor than on paper because the color gamuts for each are different.

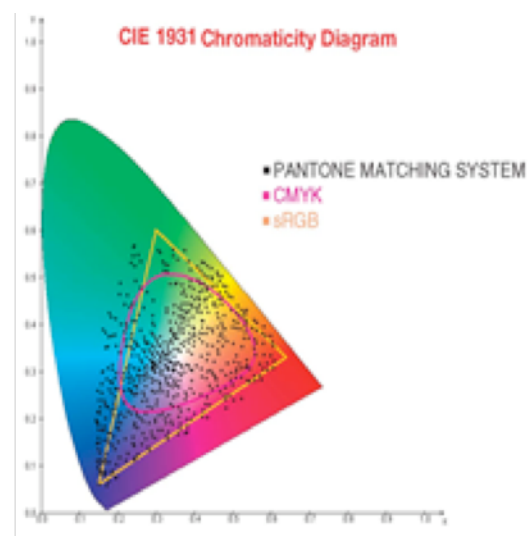


Figure 1: CIE Color Gamut that shows the print boundaries of CMYK and sRGB that Pantone can surpass.

"Computer screens emit color as RGB (red, green, blue) light" ("RGB versus CMYK"). RGB are additive colors, meaning that when the colors are added together on screen, they create a color. CMYK pigments, on the other hand, are subtractive colors because they subtract "varying degrees of red, green and blue from white light to produce a selective gamut of spectral colors" (RGB versus CMYK"). Figure 2 shows the differences of how RGB and CMYK combine to create colors.

Figure 2: RGB, left, creates white light when fully combined and CMY, right, combines to make black.

Because RGB and CMYK create color differently, one with additive light and the other with light wavelength reflection, it is difficult for a color to appear the same in both color spaces.

"In practice, Pantone is favored for solid colors such as those used in logos and letterhead; while CMYK is favored for mixed colors such as those evident in multi-colored photographs" ("Matching Pantone"). The use of Pantone ink allows for a richer color on paper, whether it is on coated, uncoated or matte paper when compared to a process color version. When the use of PANONE inks is too expensive, there are other options for conversion. Pantone offers the 4-Color Process Guides that include the CMYK values for each color ("Pantone: what we do"). The purpose of this feature is to let graphic designers plug those measurements into their choice of design software to replicate that color to the best of the software's capability.

In Adobe Illustrator software, there are over ten types of Pantone Swatch Libraries including the most popular Pantone solid coated and matte and Pantone process coated and uncoated. To convert a Pantone spot color to four-color process, there is an automated conversion button that switches the Pantone color value to CMYK values. It also depends on what type of color mode the file is formatted in because it may convert the colors to CMYK when the file is exported as a PDF. When making a file to be printed with any type of color, it is vital that attention be paid to conversion opportunities that may occur throughout the steps from creation to print.

Raster Image Processors

In order for a file to go from digital to print, it must go through a raster image processor, or a RIP, which then sends the newly translated file to the digital press in a format that the printer can read. “A RIPs basic job is to take vector graphics data and convert it to bitmapped graphics” (Dulis). When a file is sent to a RIP, it converts the vector data into a raster image, or a bitmapped image, and looks up the colors within the file on a color lookup table for each pixel and then the new high-resolution raster image is sent to the printer. Adobe’s Postscript file type is commonly used and generally accepted as a primary printing language in today’s digital printing industry. Each pixel in the bitmapped image carries information about what colors make it up. The RIP must process them correctly so the printed piece resembles the onscreen file as close as possible. EFI (Electronics for Imaging, Inc.), a leading company in the digital technology industry, created the Fiery Digital Print Solution product line that includes RIPs and Fiery Command Workstation, along with many other products (“Overview”). Fiery Command Workstation is a software tool that allows printers to see what files have been ripped, choose what settings to apply to each file and release them to the printer when desired.

Fiery Command Workstation. For this project, only toner-based printers using EFI Fiery Rips and Command Workstation 5 to organize and edit their files were selected "Fiery Command WorkStation is the recognized industry standard for production printing job management technology, serving as the window into the entire printing workflow" ("Downloads," 2009). It allows printers edit the colors within the file, color match, create page layouts, select what trays each page is coming from within the printer, adjust page alignment, and other various file managing options. According to Frank Mallozzi, senior vice president of worldwide sales and marketing at EFI, this software is helping printers "gain more productivity from their equipment, reduce errors and waste, and ultimately raise the profitability of each job" ("Downloads," 2009).

Digital Presses

Toner-based digital presses are being coming increasingly more common within printing companies due to its user-friendly operating process. There is no need for blankets, fountain solution, ink trays or pre-imaged plates. The general printing procedure for a laser printer, like the ones being used in this project, start with a piece of paper passing by a photoreceptor drum that has either positive or negatively charged areas, which will attract or reflect the toner that is to be transferred to the substrate, constructing the image of the file. Cyan, magenta, yellow and black toner, a fine-powder, acts as the inks for digital presses that is positively charged so when the paper passes by the roller, a transfer corona wire negatively charges the paper transferring positively charged toner to the substrate in the desired location, creating an image ("Laser Printing," 2011). This process is repeated for each of the process colors within the press. The completed image goes through a fuser roller that heats and melts all of the toner to the substrate, finishing the image transferring process.

The toner-based printers being used for this project are a Xerox DocuColor 2060, Ricoh Pro C900s, and a Konica Minolta bizhub Press C8000. The Ricoh and Konica Minolta presses are capable of printing at offset-quality color at 1200 x 1200 dpi resolution and the DocuColor press is only capable of printing at 600 x 600 dpi resolution (“Ricoh Pro C900s”, “bizhub PRESS C8000”, “DocuColor™ 2060”). All three presses also have EPI Fiery RIPs along with the same Command Workstation 5 software. The Ricoh has a Fiery System 8 Release 2, the Konica Minolta has a Fiery System 9 Release 2 and the DocuColor has a Fiery System 3, a much older RIP system than the others.

Calibration. In order for a printer to produce colors that are as accurate and as close to the color on a monitor as possible, it must be calibrated. That means that the press should be able to reproduce colors in a file correctly if calibrated to the press’s factory calibration settings and standards. Calibration is crucial when trying to reproduce Pantone colors because they are so unique. Writers from *Graphic Arts Monthly*, Abhay Sharma and Martin Habecost (2008), said:

> Users of digital printing presses routinely attempt to match output to specified color data. Digital press manufacturers should have a system that can create any desired color on their device-it is important that vendors understand how their toners mix and how to maintain a neutral gray. (p. 64)

Colors shift with digital presses due to an aging press, pressroom temperature shifts, and humidity changes. Quality printer operators should be able to work with their surrounding conditions to keep color consistent between each job and use spectrophotometers to adjust the toner amounts being applied according to a target sheet’s data printed from the press to the server to comply with the ICC profiles set in place. ICC stands for International Color Consortium that creates a “standard specification used by color management products. An ICC Profile is a file created to translate the color requests the computer sends to the printer” (Dimov, 2007). Those specific profiles within the server dictate how colors will be printed, so calibrating the press to match the color data is a necessary step in the printing process for press operators.

Spectrophotometers

“Graphic arts companies will try everything to meet customers' color expectations. For many customers, color is the most important criterion to accept or reject a print job” (“Measuring up,” 2008). Because Pantone colors are so distinctive, a printers’ ability to reproduce them with CMYK toner is difficult. However, a tool that helps printers get as close to the original Pantone colors but stay within the limits of the visual color gamut is called a spectrophotometer. Spectrophotometers are measuring instruments used in the printing industry to calibrate presses as well as measure and report the spectrum of a print sample. “The spectrum is the most complete descriptor of a color and is a plot of reflectance of [a] sample in all wavelengths from blue to green to red” (Sharma, 2008). This tool measures the reflected light of a color patch and then converts it into CIE L*a*b* values. CIE L*a*b* values determine how light or dark a color is, their red and green levels and their yellow and blue levels (“Color Difference”). To compare the Pantone target test sheet printed by the DocuColor, Ricoh and Konica Minolta presses and the Pantone swatch book, a spectrophotometer will be used to measure the CIE L*a*b* values and then the difference between the two will be calculated and expressed as a Delta E value. Delta E is “a single number that expresses total color difference which includes: lightness/darkness, redness/greenness, yellowness/blueness” (“Color Difference”). If the Delta E is lower than 5.0, then to most observers, the colors will look the same. If the Delta E is higher than 5.0, the digitally printed version compared to the actual Pantone version is noticeably different. The further away from 5.0 the sample is, the more different it appears when compared back to the reference color. Comparing the test sheets from the three presses to a Pantone swatch book will help determine how similar or differently the colors are reproduced and how close the CMYK versions are to the Pantone swatches.

Chapter Three: Research Methodology and Procedures

The Pantone Matching System (PMS), a standard for spot colors, is widely used by designers as a means to explore the expanded color gamut that Pantone colors are able to produce. Because some of Pantone's colors are out of the gamut that CMYK are able to create, it becomes a challenge when the use of the four-process colors is the only option available to reproduce those colors on a digital press. The purpose of this study was to measure and compare how closely the default settings within a printer's system produce Pantone colors with cyan, magenta, yellow, and black toner on digital presses. By using a spectrophotometer to measure the differences between the three Pantone target test sheets compared to a Pantone swatch book, it determined how accurately digital presses, using their default settings, would reproduce Pantone colors.

The experimental research resulted in quantitative data that was used to compare the three digital presses and their outcomes. To test each printer and their RIPs, a Pantone target sheet was created in Adobe Illustrator with a variety of 45 Pantone colors available in the software. The document was in CMYK mode and all of the color swatches that were compared came from the Pantone Solid Uncoated color book within Illustrator. Once the target sheet was created, it was saved as an Adobe PDF with 'No Color Conversions' so there are fewer color adjustments between the creation of the document to when the file is printed. This helped better evaluate how each version of the RIPs and printers interpret the Pantone colors. The file was sent to the digital presses through a program called Command Workstation 5 that helps with the settings for the RIP where all of the color conversion settings were set to default.

Before the target sheets were printed, tests were completed on the Pantone swatch book to find a similar quality substrate to do the print testing on. The papers must be alike so the results would be valid. Testing determined the brightness of the paper and if there is a coating on it or not. From the results and the decision of what paper type to use was made, all of the printer settings were set to default so there are no specialized color conversions when the file was being printed. Along with the Pantone test sheet, a GRACoL target test sheet was printed as well to create profiles on the printers to help get closer readings after the first initial press run.

After the files were sent through the RIPs for the DocuColor 2060, Ricoh Pro C900s, and Konica Minolta C8000, the Pantone test sheet and GRACoL sheet were printed with toner on HP LaserJet 8.5" x 11" paper with 98 brightness that was determined to be closest to the Pantone swatch book. Then, an X-Rite 530 spectrophotometer was used to measure the CIE L*a*b* differences in the readings to determine how closely digital presses are capable of printing Pantone colors with only process color toner and compare them to the swatch book printed by Pantone.

Next, the GRACoL targets were used to create a profile to make color adjustments with software called Profile Maker. Once profiles were created for each press, they were embedded into the Illustrator file for each printer and were saved as PDFs with the Profile Inclusion Policy including all profiles. The Pantone test sheets were printed again, the new CIE L*a*b* measurements were recorded again from the spectrophotometer and then compared to the first run and the actual Pantone swatches.

The hypothesis was that after using the profiles to adjust the color output, the CIE 1994 (graphic arts) Delta E values for all three presses would be smaller than the values of the colors without the profiles.

The CIE 1994 (graphic arts) Delta E equation (and what each variable means) is the following:

$$\Delta E = \sqrt{\left(\frac{\Delta L}{K_L S_L}\right)^2 + \left(\frac{\Delta C}{K_C S_C}\right)^2 + \left(\frac{\Delta H}{K_H S_H}\right)^2}$$

$$\Delta L = L_1 - L_2$$
$$\Delta C = C_1 - C_2$$
$$\Delta H = \sqrt{\Delta a^2 + \Delta b^2 - \Delta C^2}$$
$$C_1 = \sqrt{a_1^{\,2} + b_1^{\,2}}$$
$$C_2 = \sqrt{a_2^{\,2} + b_2^{\,2}}$$
$$\Delta a = a_1 - a_2$$
$$\Delta b = b_1 - b_2$$
$$S_L = 1$$
$$S_C = 1 + K_1 C_1$$
$$S_H = 1 + K_2 C_1$$
$$K_L = \begin{cases} 1 & \text{default} \\ 2 & \text{textiles} \end{cases}$$
$$K_C = 1 \quad \text{default}$$
$$K_H = 1 \quad \text{default}$$
$$K_1 = \begin{cases} 0.045 & \text{graphic arts} \\ 0.048 & \text{textiles} \end{cases}$$
$$K_2 = \begin{cases} 0.015 & \text{graphic arts} \\ 0.014 & \text{textiles} \end{cases}$$

The results would show which of the three presses had the most improvement and which one got the closest to the original swatches and stretched the limits of toner producing Pantone colors out of the CMYK color gamut using the default settings of the printers.

Chapter Four: Results and Discussion

The purpose of this study was to determine how closely cyan, magenta, yellow and black toner could reproduce Pantone colors on digital presses and if the use of a GRACoL profile would help make improvements. After printing the 45 Pantone colors (figure 3) without a profile, the ΔE_{94} values for the DocuColor, Ricoh, and Konica Minolta color outputs using the CIE L*a*b* measurements from the X-Rite 530 spectrophotometer were calculated. After the profiles were created and embedded into the PDFs, the test sheet was printed again and those numbers were recorded as well. Then using the CIE L*a*b* measurements, the ΔE_{94} values calculation were used to find the differences between the print samples and the reference swatch colors.

Figure 3: 45 Pantone colors used to measure and test three digital printers.

As mentioned previously, if the Delta E value is lower than 5.0, the color difference is not visibly noticeable. If it is higher than 5.0, the colors are visibly different.

The averages for each ΔE_{94} value per printer are listed in table 2 below:

	Konica Minolta w/o Profile	Konica Minolta w/ Profile	Ricoh w/o Profile	Ricoh w/ Profile	DocuColor w/o Profile	DocuColor w/ Profile
ΔE_{94} Average	5.23	5.23	11.41	11.46	10.35	6.79

Table 2: ΔE_{94} averages of all three printers with and without the use of a color profile.

A human error had been made when measuring the CIE L*a*b* numbers for Pantone colors 250 U and 3935 U so their ΔE_{94} values were not included into the averages of each press.

The Konica Minolta C8000 press had the exact same average of 5.23 with and without the use of a color profile. This printer has an internal image controller called an IC-601. "It offers various highly functional features including high-speed RIP processing, enhanced color image reproduction, [and] high speed image transfers" ("Konica Minolta"). Because it has this internal color management system, colors printed were interpreted the same way, resulting in the same ΔE_{94} value average. The colors that the Konica Minolta had the most difficulty matching to the original Pantone swatches without a profile were 324 U, 421 U, and 7547 U. After the profile was embedded, the colors with the highest ΔE_{94} values were 324 U still, 1375 U, and 1225 U.

The DocuColor 2060 was the only printer that was positively affected by the use of the color profile. With a ΔE_{94} value drop of 3.60, all of the Pantone colors were still noticeably different than the Pantone Swatch book. This press is about 13 years old, whereas the Konica Minolta and Ricoh are only a couple of years old, so its RIP does not have the same type of color management system that is capable of interpreting the Pantone colors as accurately without a color correcting profile. However, the DocuColor did produce the smallest ΔE_{94} value for any color, with or without a profile, than either of the other printers. The ΔE_{94} value for 2707 U was only 1.61 without the use of a profile. It also had the biggest improvement by the profile for 209 U from 21.26 without the profile to 2.72 with the profile. The colors that the DocuColor had the most difficulty matching without a profile were 209 U, 269 U, and 3308 U. After the profile was embedded, the colors with the highest ΔE_{94} values were 2715 U, Green U, and 324 U.

The Ricoh Pro C900s had about the same ΔE_{94} value average with and without the color profile with a difference of only 0.05. That meant that the color management system within the EFI Fiery RIP was generally reproducing the same way as it did with the GRACoL profile. The RIP interpreted the colors as accurately as it could for both print runs. The colors that the Ricoh had the most difficulty matching without a profile were 2715 U, 410 U, and 424 U. After the profile was embedded, the colors with the highest ΔE_{94} values were 2715 U and 410 U again, along with 7533 U.

Overall, only the Konica Minolta C8000 press averaged just above the point in which the color difference of the test sheet and Pantone swatch became noticeable at 5.23. That showed that with simple default settings, these digital presses, with only the use of process color toners, generally were unable to create Pantone colors from the Uncoated Solid color book. Only the DocuColor 2060 increased its color accuracy with the GRACoL profile, disproving the hypothesis that all of the printers will improve after a profile was embedded into each of the Pantone test sheet PDFs.

Chapter Five: Conclusions

The Pantone Matching System was created so graphic designers, along with packaging designers and interior designers, were not limited to only what cyan, magenta, yellow and black inks could physically produce. Now with thousands of colors to choose from, Pantone expanded the color gamut in which designers had to choose from for print and digital material because these spot colors were specially developed from the fourteen basic Pantone colors and pigments, as opposed to the four process colors, which have restricted combination abilities.

Combine the current popularity of PMS colors with the increasing prevalence of digital presses in print companies and there will be a greater need for color accuracy and press customization. As evidenced in this study, a Xerox DocuColor 2060, Ricoh Pro C900s, and a Konica Minolta bizhub Press C8000 had difficulty producing Pantone colors with ΔE_{94} values at 5.0 or under using all default settings, even with the help of a GRACoL color correcting profile. With the embedded profile in the Pantone test sheet PDF, the DocuColor printed some of the 45 Pantone colors more closely to the actual Pantone swatches, but most were still visibly different. The Konica Minolta had the lowest average of the ΔE_{94} values from both rounds of printing that did not change, because it has an internal color management system that could interpret the colors as accurately as possible under the testing conditions with and without a profile. The Ricoh also did not improve from the first print run to the second because it has a RIP that also interpreted the colors as best it could with default settings.

Ultimately, digital presses struggle reproducing spot colors with CMYK because those colors were not meant to be printed with process toners. However, with color correction profiles and customized printer settings, it is possible to improve spot color output.

References

Color Difference Matters. (n.d.). Retrieved from https://www.sabicip.com/staticcxp/user/en/LearnAboutColor/ColorBasicsDetail/color_diff_measurement.html.

Dimov, C. (2007, October 28). Spectrophotometer – frill or norm?. Retrieved from http://graphicartsmag.com/articles/2007/10/spectrophotometer—frill-or-norm.

DocuColor™ 2060. (n.d.). Retrieved from http://www.xerox.com/digital-printing/printers/digital-press/docucolor-2060/spec-enus.html.

Dulis, P. (2003, 20 July). To RIP or not to RIP. Retrieved from http://graphicartsmag.com/articles/2003/07/to-rip-or-not-to-rip.

Downloads exceed 10,000 in first three months for latest Fiery Command Workstation software. (2009, August 5). *Business Wire.* Retrieved February 18, 2012, from ProQuest Newsstand.

Konica Minolta Bizhub PRESS C8000. (2011, January). Retrieved from http://www.konicaminolta.com.au/library/BERTL_C8000_5-Star_Test_Report.pdf.

Laser Printing Process. (2011, March 8). Retrieved from http://ciscoskills.net/2011/03/08/laser-printing-process/.

Lindbloom, B. (n.d.). Color Difference Calculator. Retrieved from http://www.brucelindbloom.com/index.html?ColorDifferenceCalc.html.

Matching Pantone to CMYK color. (n.d.). Retrieved from http://www.psprint.com/resources/printing-tips-and-techniques/general/matching-Pantone-cmyk-color.asp.

Measuring Up. (2008, December 1). Retrieved fromhttp://americanprinter.com/work-flow/measuring-up-1208/).

Pantone announces uncoated version of new Pantone Goe System. (2008, May 29). Retrieved from *ProQuest Newsstand, ProQuest*.

Pantone: What we do. (n.d.). Retrieved from http://www.Pantone.com/pages/Pantone/Pantone.aspx?pg=19295.

RGB versus CMYK. (n.d.). Retrieved from http://www.printernational.org/rgb-versus-cmyk.php.

RGB versus CMYK. (n.d.). [Figure 2]. Retrieved from http://www.printernational.org/rgb-versus-cmyk.php.

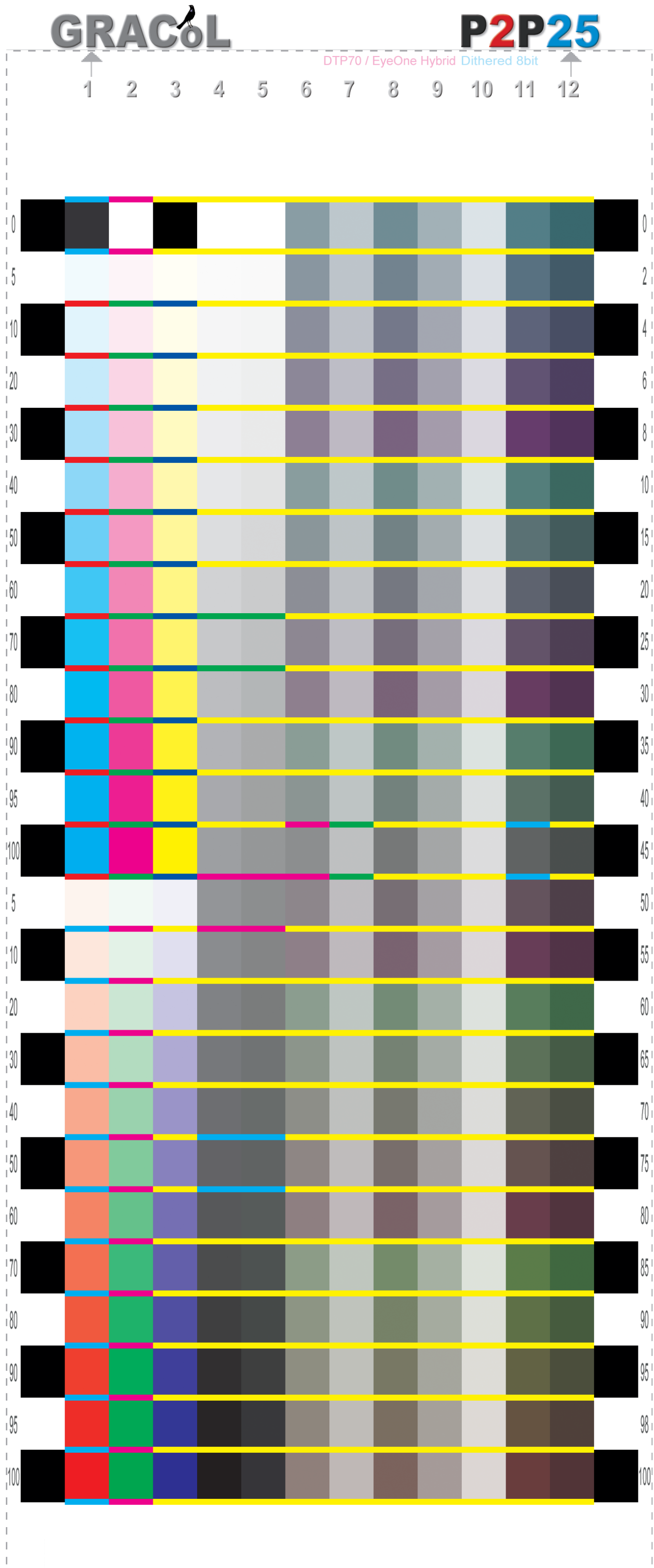
Sharma, A. (2008). Color management for packaging: Spectral colors & beyond. Retrieved from http://www.flexoglobal.com/flexomag/08-May/flexomag-sharma.htm.

Sharma, A. & Habecost, M. (2008, May). Digital presses: See how they run. *Graphic Arts Monthly, 80*(5), 64. Retrieved February 18, 2012, from ABI/INFORM Global.

Solid Color Information. (n.d.). Retrieved from http://www.Pantone.com/pages/Pantone/Pantone.aspx?pg=20459&ca=1.

Appendix

Pantone Names	Konica Minolta w/o Profile ΔE_{94}	Konica Minolta w/ Profile ΔE_{94}	Ricoh w/o Profile ΔE_{94}	Ricoh w/ Profile ΔE_{94}	DocuColor w/o Profile ΔE_{94}	DocuColor w/ Profile ΔE_{94}
107 U	4.88	5.57	6.16	7.39	4.95	4.72
1225 U	6.86	7.86	10.96	11.38	8.32	9.03
1375 U	6.50	8.36	12.46	13.08	9.79	12.09
166 U	2.76	3.52	8.64	9.77	9.39	3.12
185 U	5.41	6.88	9.56	10.58	10.88	10.44
209 U	4.93	7.38	10.83	13.26	21.26	2.72
2395 U	5.54	7.58	11.69	11.06	17.63	12.04
269 U	3.77	4.63	14.83	14.74	23.65	6.79
2707 U	4.40	4.20	6.73	6.65	1.61	5.81
2715 U	5.10	5.22	17.04	16.40	16.14	15.29
2735 U	3.35	4.75	13.31	14.66	18.90	8.78
2767 U	4.45	4.49	10.18	12.58	19.59	4.31
297 U	5.81	6.27	11.06	9.91	8.13	6.85
302 U	3.98	2.98	12.13	12.94	11.59	6.56
3135 U	5.76	4.82	10.53	9.53	4.86	7.51
3165 U	4.30	3.24	8.66	8.35	10.40	3.84
324 U	9.25	10.27	14.64	13.44	8.24	10.73
3272 U	4.94	5.66	10.45	11.28	5.37	9.55
328 U	4.09	2.37	11.92	12.87	4.22	3.71
3308 U	5.59	4.90	10.07	12.62	21.56	5.13
358 U	4.89	5.74	9.02	9.44	6.98	7.62
361 U	2.08	2.89	14.18	14.78	9.22	8.48
363 U	3.91	5.04	13.87	12.87	9.48	4.73
382 U	3.74	4.33	10.57	10.52	5.96	8.44
3965 U	3.52	3.57	7.65	7.51	5.65	7.16
399 U	3.40	2.11	9.51	8.96	8.14	4.02
402 U	7.66	6.89	11.49	10.62	4.00	6.29
406 U	6.39	6.67	10.40	10.38	3.44	7.76
410 U	6.25	5.34	15.81	16.77	11.56	5.56
421 U	8.09	6.96	12.17	10.84	3.40	8.03
424 U	6.81	5.56	15.96	14.98	7.06	6.27
430 U	6.74	5.36	15.11	14.08	1.06	6.78
456 U	3.22	1.93	10.49	9.86	9.66	2.08
4715 U	6.19	3.92	8.52	8.75	9.07	3.68
492 U	6.71	5.12	11.77	10.62	11.51	3.86
494 U	6.14	5.42	8.67	6.76	4.46	4.84
676 U	4.96	5.79	11.83	10.56	12.26	6.38
7511 U	3.45	4.05	14.37	12.70	13.57	5.64
7515 U	5.69	5.07	9.69	9.21	7.88	3.54
7517 U	5.39	6.17	14.90	14.84	15.00	5.28
7533 U	5.69	4.83	14.01	15.19	20.55	7.37
7547 U	7.79	6.79	5.92	6.05	20.35	4.88
Green U	4.52	4.20	12.76	13.96	8.40	14.37


GRACoL
P2P25
DTP70 / EyeOne Hybrid Dithered 8bit
1 2 3 4 5 6 7 8 9 10 11 12